RESEARCH BULLETIN 1012 MAY 1968

Modifications in Diammonium Phosphate as a Nitrogen Source for Ruminants

RONALD R. JOHNSON

K. E. McCLURE

OHIO AGRICULTURAL RESEARCH AND DEVELOPMENT CENTER
WOOSTER, OHIO

CONTENTS

* *

AGDEX 400/55-67

5-68-2.5M

Modifications in Diammonium Phosphate as a Nitrogen Source for Ruminants[1]

RONALD R. JOHNSON and K. E. McCLURE

INTRODUCTION

The use of non-protein nitrogen in ruminant rations increases every year and urea continues to be the major source of this non-protein nitrogen. Even though feed formulations have now been devised with which urea may be safely used in relatively high proportions, researchers continue to look for other sources of non-protein nitrogen which may be less toxic than urea and possibly more economical.

One potential source of non-protein nitrogen which has the possibility of being economically competitive with urea is diammonium phosphate (DAP). DAP is widely used in the fertilizer industry as a source of both nitrogen and phosphorus. However, only limited studies have been conducted on the use of DAP as a source of non-protein nitrogen or phosphorus for animals. Earlier studies in this laboratory (3) using crystalline DAP suggested that it was quite unpalatable as a supplementary source of nitrogen for ruminants. Similar studies elsewhere showed that both granular and crystalline DAP were unpalatable. Interest in DAP as a non-protein nitrogen source continued, however, because it represented a compound which furnished not only non-protein nitrogen but supplementary phosphorus as well. Thus it has potential use in areas where both protein and phosphorus deficiencies exist simultaneously, such as in grazing or range conditions.

Diammonium phosphate when mixed with water is usually characterized by an evolution of ammonia from the water suspension or solution. It is assumed that a similar evolution of ammonia is responsible for the low palatability of this supplementary material when it is taken into the mouth of the ruminant. Therefore, this study was initiated to investigate means of preventing this immediate release of ammonia from the diammonium phosphate and hopefully to increase the palatability of the material in mixed rations.

The objectives of this study were: (1) to determine the ability of coating materials to slow the access of water to the diammonium phosphate granules and thus to slow the release of ammonia, (2) to study the ability of coated diammonium phosphate granules to support rumen

[1]Supported in part by a gift in aid of research by the Smith-Douglass Division of the Borden Chemical Company, Plant City, Florida.

microbial activity *in vitro,* and (3) to study the palatability and digestibility of mixed ruminant rations containing diammonium phosphate and coated diammonium phosphate. The laboratory and animal feeding phases of the experiment are considered separately in this report.

LABORATORY STUDIES

Materials and Methods

Several coating materials were obtained and used to coat diammonium phosphate granules as described in Table 1. The first six samples (SD-1 through SD-12) were applied in this laboratory in the melt form. Diammonium phosphate granules were poured into a beaker of the melted coating material so that about 1/3 to 1/2 of the volume was contributed by diammonium phosphate granules. The beaker was then cooled by placing it in a cold water bath. After solidifying, the material was removed and broken into small particles or crumbles by a coarse grinding technique with a mortar and pestle. By sieving this material through a screen, most of the fine particles of the coating material could be removed, leaving primarily coated diammonium phosphate granules. Samples SD-101 through SD-105 were specially formulated diammonium phosphate materials prepared by the Smith-Douglass Company.

Release of ammonia from the coated materials when suspended in water was determined for time periods of 10, 30, and 60 minutes and 5 and 24 hours. Known quantities of the coated materials were weighed into tubes for each of the time periods to be tested and water was placed in the tubes at zero time. After the prescribed time period, the entire contents of the tubes were filtered into a distillation flask and the diammonium phosphate materials were rinsed with water in the filter paper.

TABLE 1.—Description of Coated DAP Materials and Specially Prepared Products.

Lab. No.	Material Description	M.P. °C.	How Applied
SD-1	Lactic Acid Ester	62	Melt
SD-2	Hydrogenated Triglyceride	68	Melt
SD-5	Hardened Tallow Fatty Acid	55	Melt
SD-9	Hydrogenated Mono-Di-Glyceride No. 2	65	Melt
SD-11	Tallow Fatty Alcohol (70%) plus Hydrolyzed Animal and Vegetable Fat (30%)		Melt and Kaolin
SD-12	Castor Wax	86	Melt
SD-101	Smith Douglass Project C-2B Sample 1		
SD-102	Smith Douglass Project C-2B Sample 2		
SD-103	Smith Douglass Project C-2B Sample 3		
SD-104	Smith Douglass Project C-2B Sample 4		
SD-105	Smith Douglass Project C-2B Sample 5		

This procedure insured that the ammonia which was not released prior to the distillation would not be disturbed or disrupted by the distillation procedure and alter the results to be obtained. A similar procedure was followed for all materials tested. The ammonia in the solution was then distilled over magnesium oxide into a boric acid flask and titrated.

The utilization of the nitrogen from the coated and test materials by rumen microorganisms was determined by using these materials as nitrogen sources for cellulose digesting cultures of rumen bacteria grown *in vitro*. The *in vitro* procedure was essentially that reported earlier (2). The cellulose substrate and usual media were placed in the *in vitro* fermentation tubes and the nitrogen source added at the time of inoculation with rumen bacteria. By so doing, there was no opportunity for the coated material to be disrupted by water or the media prior to the addition of the rumen bacteria inoculum. Thus, inoculation time was zero time for both bacterial growth and nitrogen release. Cellulose digestion was determined after 30 hours of incubation by centrifuging the entire contents of the fermentation tubes and determining residual cellulose on the sediment by the Crampton and Maynard method (1).

Since some diammonium phosphate preparations contain significant quantities of fluoride, the toxicity of fluoride to the rumen bacteria was determined. This was accomplished through *in vitro* rumen fermentations similar to those described earlier. When cellulose was used as the substrate, both the cellulose digestion and synthesis of trichloroacetic acid (TCA) precipitable nitrogen were used as criteria of bacterial activity. Starch was also used as a substrate in similar fermentations, with only the TCA precipitable nitrogen used as the criteria of activity. With both substrates, graded levels of fluoride were added at the beginning of the experiments, using a solution of sodium fluoride as the source.

Results and Discussion

The release of distillable ammonia from three coated diammonium phosphate samples and five specially treated samples is shown in Figures 1 and 2. Uncoated DAP was used as a reference standard in all experiments but highly variable results were obtained with uncoated DAP. In some experiments, as much as 70% of the material was distillable at 10 minutes from DAP; in other experiments, 10 to 15% was distillable at the same interval. Because of this high variability, the reference curves for diammonium phosphate are not shown in the figure.

There are some marked differences observable in the release curves for the materials tested. For example, both SD-11 and SD-105 gave the lowest release of distillable ammonia at the 10-minute period. This trend continued throughout the entire experiment. SD-1 and SD-12

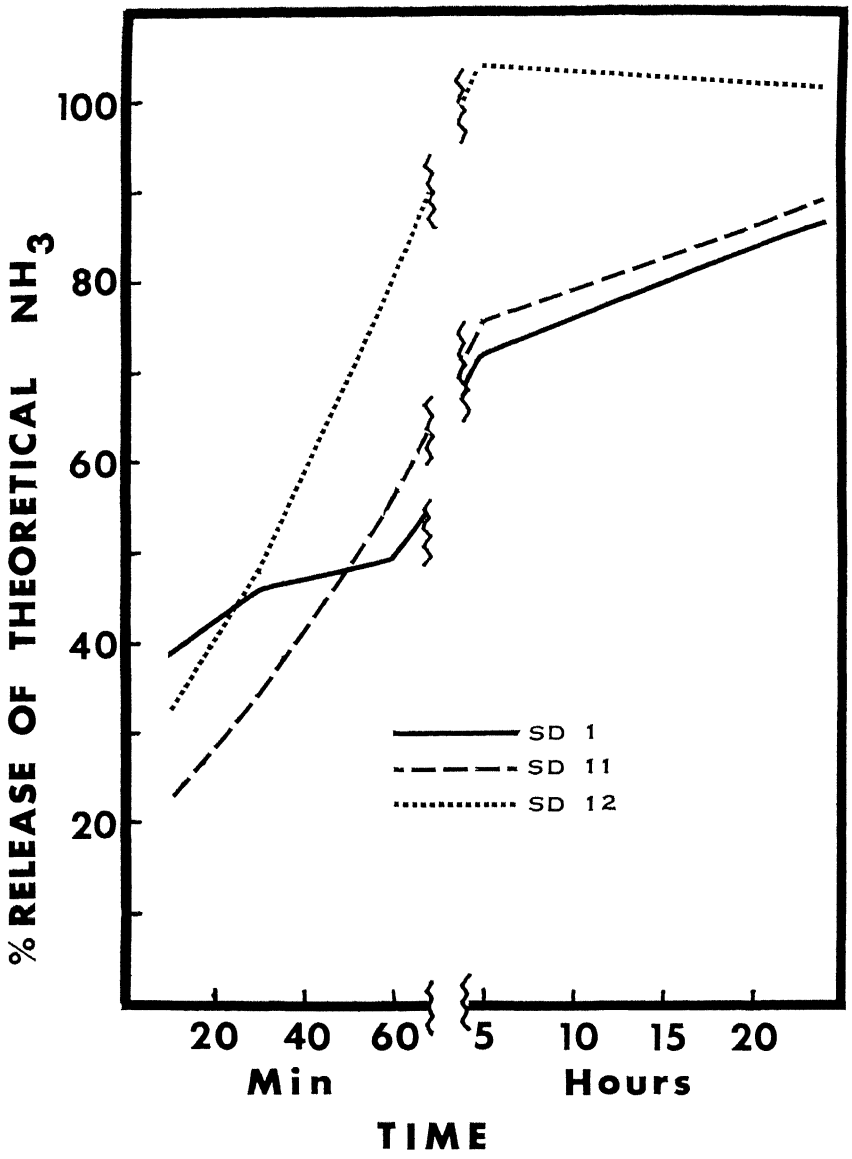

Fig. 1.—Release of ammonia from coated and treated DAP products.

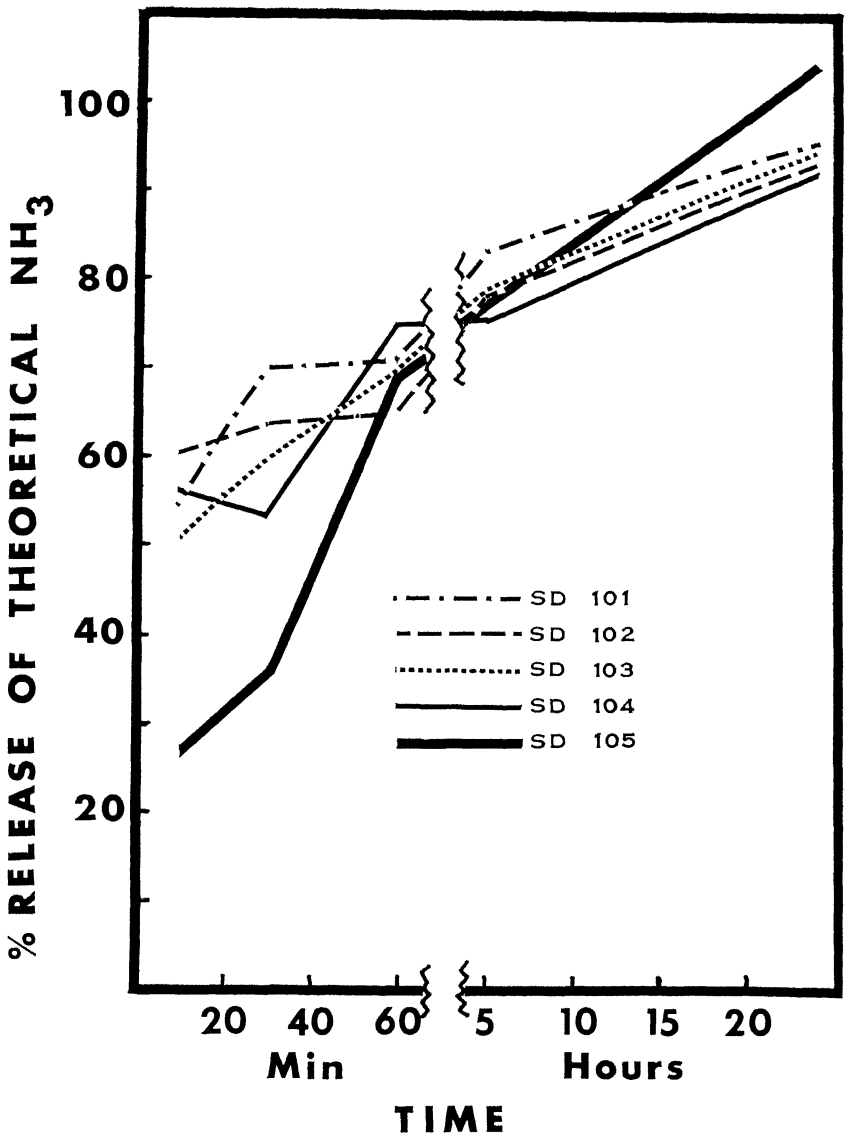

Fig. 2.—Release of ammonia from coated and treated DAP products.

also had rather limited availability at this early time period. SD-101 through SD-104, on the other hand, were more than half available for distillation at the 10-minute period. This would be considered a rapid release of the distillable ammonia.

Most of the materials approached 100% release at 24 hours. The failure of some materials to reach 100% is partially due to the fact that with the large coated granules used in some of the preparations, it was difficult to measure the exact quantity of nitrogen present in the flask. Thus, the theoretical value was merely an estimate and not an exact figure.

The cellulose digestion data from the *in vitro* fermentations are shown in Table 2. Both urea and diammonium phosphate were included as standard nitrogen sources for comparison. The lack of homogeneity in the coated samples again caused considerable variability. For the most part, however, the materials tested were capable of supporting microorganism activity to almost the same extent as urea or DAP.

SD-1, SD-5, and SD-105 exhibited somewhat lower activity than the rest of the samples. SD-105 routinely demonstrated slightly lower activity than any other samples. The coating materials used to make SD-1 and SD-5 were then tested for toxicity by merely including some of the coating material itself in fermentation flasks in which urea was

TABLE 2.—Cellulose Digestion in Vitro **Using Coated DAP and Specially Treated DAP Materials as Nitrogen Sources.**

Nitrogen Source	Number of Trials	Average 30-Hour Cellulose Digestion, %
	Coated DAP Materials	
Urea	5	51.3
DAP	3	45.7
SD-1	5	42.5
SD-2	2	51.4
SD-5	2	41.8
SD-9	2	45.8
SD-11	5	52.3
SD-12	5	53.5
	Specially Treated DAP Materials	
Urea	3	50.9
DAP	2	50.9
SD-101	3	57.0
SD-102	3	50.4
SD-103	3	50.1
SD-104	3	48.0
SD-105	3	41.0

used as the source of nitrogen. In this series of experiments, SD-5 demonstrated some toxicity. The cause of this toxicity is unknown. However, it should be noted that this material had the lowest melting point of any material used in any of the tests.

The toxicity of fluoride on *in vitro* fermentations is illustrated in Figure 3. In cellulose digesting cultures, fluoride appeared to be toxic after

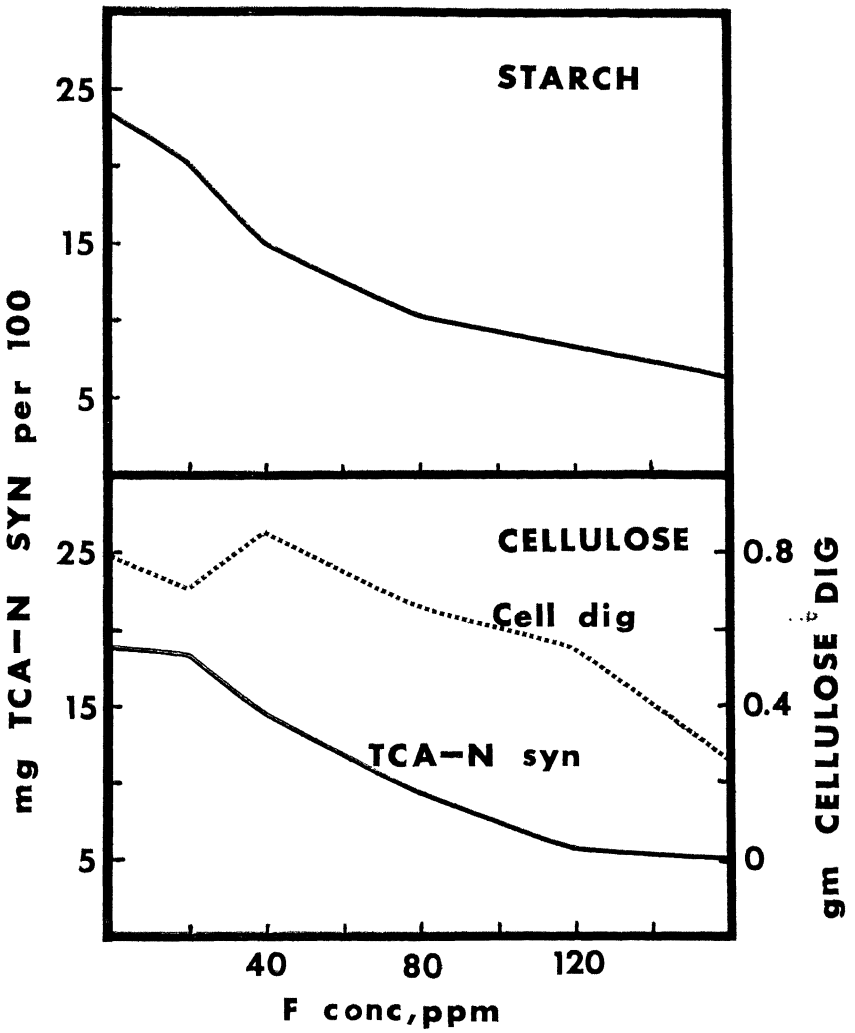

Fig. 3.—Toxicity of fluoride (F) for rumen microorganisms when digesting cellulose or starch in 30-hour in vitro **fermentations TCA—N = trichloroacetic acid precipitable nitrogen.**

levels of 20 ppm had been reached, especially when TCA precipitable nitrogen synthesis is considered. It would appear that this was not highly inhibitory to cellulose digestion until levels of approximately 80 ppm or greater were reached, using the 30-hour digestion figure.

With starch digestion, fluoride appeared to be toxic at 20 ppm and further additions appeared to be successively more toxic. Since most rumen fermentations in the animal involve digestion of several types of carbohydrates simultaneously, it is impossible from these data to state the exact toxicity level of fluoride. Under the conditions tested here, however, 20 ppm may be toxic.

ANIMAL TRIALS

Materials and Methods

The trials outlined below were designed to determine if modifications of diammonium phosphate granules improved the palatability of rations utilizing these materials as supplementary sources of nitrogen. The digestibility and retention of nitrogen by sheep on these same rations were also studied. The composition of the rations and the description of the supplementary nitrogen materials are shown in Table 3.

The first phase of the animal feeding investigation consisted of two palatability trials known as the comparison trial and the *ad libitum* trial.

In the comparison trial, the animals were given a choice of two feed mixtures at a time and for a period of 3 weeks. The feeds were offered in one feed box which was divided into two sections. The feed was weighed into the boxes each day and weighed back the following morning

TABLE 3.—Composition of Rations for the Palatability and Digestion Trials.

	Ration						
Ingredient, %	**1**	**2**	**3**	**4**	**5**	**6**	**7**
Chopped hay	45	45	45	45	45	45	45
Ground shelled corn	49.81	49.79	49.32	49.97	50.51	44.7	49.36
SD-1-SD	2.99	—	—	—	—	—	—
SD-101	—	4.51	—	—	—	—	—
SD-105	—	—	3.48	—	—	—	—
DAP-SD	—	—	—	2.83	—	—	—
Urea	—	—	—	—	1.19	—	—
Soybean oil meal	—	—	—	—	—	7.10	—
SD-1-OAES	—	—	—	—	—	—	3.44
Trace mineral salt	0.50	0.50	0.50	0.50	0.50	0.50	0.50
Dicalcium phosphate	—	—	—	—	2.70	2.50	—
Limestone	1.70	.80	1.70	1.70	0.10	0.20	1.70
Vitamin A (30,000 IU/gm.) gm.	5	5	5	5	5	5	5
Vitamin D (3,000 IU/gm.) gm.	5	5	5	5	5	5	5
Sodium sulfate (gm.)	45	45	45	45	45	45	45

and refusals recorded. The feeds were switched each day from one side of the box to the other. Seven sheep were used in the comparison trial. Each comparison possible with the seven different rations was made with at least three sheep.

In the *ad libitum* trial, the animals were allowed only one ration at a time and thus no choice was possible. This was designed to determine the true palatability of the ration for the animal when it had only one experimental feed to consume. The animals were first placed on a 7-day preliminary trial in which soybean meal formed the supplementary source of nitrogen. Then the animals proceeded through a series of 7-day trials in which they were offered the other six rations to be tested. Each 7-day trial was separated, however, by a 3-day recovery period in which the animals consumed the soybean meal ration again. This was done in an attempt to insure that all animals started all trials on a similar basis with each supplement.

Six lambs were used to evaluate six of these rations in a digestion trial. Ration SD-105 was not included in the digestion trial since it was so unpalatable. The animals were placed on a basal ration (ration 6) for a period of 11 days. They were then placed on test rations for 10-day preliminary periods and 11-day collection periods and according to the Latin Square design. They were fed to approximately 10% over appetite and all refused feed was weighed accurately and discarded. Urine and feces were collected and sampled in the usual manner (2).

Results and Discussion

A summary of the comparison trial is shown in Table 4. The data are reported for actual kg. of each choice consumed daily and also as the ratio on the base of 100. Soybean meal was preferred over all other rations tested. The diammonium phosphate ration, however, was not as unpalatable as anticipated and this affected most of the later results. The urea and diammonium phosphate rations were consumed equally when fed with each other. However, the urea ration appeared better than the diammonium phosphate ration when both were compared to the other treated DAP preparations. The palatability of SD-1-SD and SD-101 appeared to be about the same as uncoated DAP, while SD-1 OAES may have been slightly better. The SD-105 was definitely unpalatable and was eliminated from the later digestion trial.

The results of the *ad libitum* palatability trial are shown in Table 5. In these data, the rations are ranked in order of increasing consumption and the range of consumption by individual sheep is given. SD-105 again is the least palatable and urea, DAP, and SD-1-SD appeared to be most palatable. Actually, all rations were palatable when average consump-

TABLE 4.—Intake of Rations Fed in Pairs and the Intake for Each Pair to the Base 100 During the Palatability Comparison Trial.

Ration A*		Ration B*						
		1(SD-1-SD) A:B	2(SD-101) A:B	3(SD-105) A:B	4(DAP-SD) A:B	5(Urea) A:B	6(SOM) A:B	7(SD-1-OAES) A:B
4	Daily intake ratio (kg.)	0.59:0:62	0.69:0.65	1.23:0.23		0.77:0.72	0.20:1.51	0.49:0.90
	Ratio (Base 100)	49:51	52:48	84:16		52:48	12:88	35:65
5	Daily intake ratio (kg.)	1.46:0.15	1.16:0.40	1.33:0.12	0.72:0.77			1.45:0.56
	Ratio (Base 100)	91:9	74:26	92:8	48:52			72:28
6	Daily intake ratio (kg.)	1.60:0.08	1.28:0.25	1.41:0.02	1.51:0.20			1.48:0.37
	Ratio (Base 100)	95:5	84:16	99:1	88:12			80:20

*Rations A and B refer to the two rations provided in a given palatability comparison. Data are given for comparisons of rations 4, 5, and 6 (A) to rations 1 - 7 (B).

TABLE 5.—Intake of Rations Fed in the Palatability ad Libitum Trial.

Ration Number	Identity	No. of Animals	Av. Daily Intake (kg.)	Range of Intake (kg.)
3	SD-105 C-2 B-5	7	1.41	0.26 to 1.91
2	SD-101 C-2 B-1	7	1.45	0.98 to 1.93
6	Soybean meal	7	1.54	1.09 to 1.86
7	SD-1-OAES	7	1.59	1.09 to 2.00
1	SD-1-SD	7	1.67	1.18 to 2.09
4	DAP-SD	7	1.70	1.27 to 2.04
5	Urea	7	1.79	1.41 to 1.95

tions were considered. The range figures suggest, however, that there is more consistency as one goes up the scale; i.e., with the least palatable material, animal preference played a more important role. The soybean meal ration was fed to all lambs at the beginning of the trial. Two possible reasons for the lower than expected intake of soybean meal are the smaller size of the lambs and a possible carryover effect from the previous comparison trial.

Table 6 shows the apparent digestibilities for dry matter and protein as determined in the digestion trial. These results are averages from six determinations on each ration. There was little difference between rations as far as digestibility was concerned. It was obvious from the range of values reported for each material that the small differences between the average values were not significant. Since all of these materials appeared to be suitable sources of non-protein nitrogen for *in vitro* rumen fermentations, no differences in digestibility in this type of trial were anticipated.

TABLE 6.—Dry Matter and Protein Digestibilities of Rations Fed During DAP Digestion Trial.

Ration	Dry Matter Digestibility, %		Protein Digestibility, %	
	Average*	Range	Average*	Range
1. SD-1-SD	64.9	57.7 to 70.4	68.6	61.8 to 72.0
2. SD-101, C-2, B-1	66.8	64.7 to 71.4	70.2	65.2 to 77.4
4. DAP-SD	66.3	63.0 to 69.3	67.5	64.4 to 71.2
5. Urea	67.8	62.9 to 75.0	73.8	69.0 to 81.8
6. SOM	67.6	61.8 to 71.1	70.3	62.1 to 74.1
7. SD-1-OAES	68.5	65.2 to 72.3	70.4	64.5 to 77.0

*Differences between means are not statistically significant.

It is important to note in the animal feeding data that the uncoated diammonium phosphate did not appear to be highly unpalatable at any time. This is contrary to some reports by other investigators who reported a considerable decrease in feed consumption when diammonium phosphate was included in the rations.

The trials reported here were conducted over a 2-year period during which the same supply of diammonium phosphate was used for all experiments. When the supply first arrived at the beginning of the study, it was noted that some free ammonia could be detected over the dry material. As time progressed, however, less of this was noted. It is possible that the labile ammonia present in some diammonium phosphate preparations may be lost over a considerable period of time and as a result, the undesirable effect on palatability may also be lost. Obviously no proof for this theory exists in the data reported here.

It can definitely be concluded that the loss or release of ammonia from diammonium phosphate can be slowed by coating the material. It can also be concluded that the coating materials tested had little effect on the palatability or on digestibility of rations containing them. However, since palatability of the diammonium phosphate was not as low as has been reported previously, it is not possible from these data to assess the real value of coating diammonium phosphate to alleviate potential palatability problems.

SUMMARY

Six preparations of diammonium phosphate coated with various lipid type materials and five specially formulated diammonium phosphate materials were tested for rate of release of ammonia in water solution, sources of nitrogen for *in vitro* rumen bacterial activity, palatability for sheep, and digestibility in sheep rations. Several coating materials were capable of slowing the release of ammonia from diammonium phosphate in water solution. With the exception of two coated materials which were slightly toxic, the coated diammonium phosphate was capable of supporting rumen bacterial activity *in vitro*.

In a comparison palatability trial, a mixed ration made with soybean meal was preferred to all other rations. Rations made with urea and DAP appeared to be equally palatable when compared to each other. In an *ad libitum* palatability trial, the urea ration was apparently the most palatable and the uncoated DAP ration was the second most palatable ration fed. Apparent digestibilities for dry matter and protein were only slightly different between rations.

LITERATURE CITED

1. Crampton, E. W. and L. A. Maynard. 1938. The relation of cellulose and lignin content to the nutritive value of animal feeds. J. Nutr. 15:383.
2. Johnson, R. R., O. G. Bentley, and T. V. Hershberger. 1962. The effectiveness of coated urea prills and copper treated urea prills as nitrogen sources for rumen microorganisms. Ohio Agri. Exp. Sta., Res. Bull. 917.
3. Johnson, R. R. and K. E. McClure. 1964. **In vitro** and **in vivo** comparisons on the utilization of urea, biuret, and diammonium phosphate by sheep. J. Anim. Sci. 23:208.

The State Is the Campus for Agricultural Research and Development

Ohio's major soil types and climatic conditions are represented at the Research Center's 12 locations. Thus, Center scientists can make field tests under conditions similar to those encountered by Ohio farmers.

Research is conducted by 13 departments on more than 6200 acres at Center headquarters in Wooster, ten branches, and The Ohio State University.

Center Headquarters, Wooster, Wayne County: 1953 acres

Eastern Ohio Resource Development Center, Caldwell, Noble County: 2053 acres

Jackson Branch, Jackson, Jackson County: 344 acres

Mahoning County Farm, Canfield: 275 acres

Muck Crops Branch, Willard, Huron County: 15 acres

North Central Branch, Vickery, Erie County: 335 acres

Northwestern Branch, Hoytville, Wood County: 247 acres

Southeastern Branch, Carpenter, Meigs County: 330 acres

Southern Branch, Ripley, Brown County: 275 acres

Vegetable Crops Branch, Marietta, Washington County: 20 acres

Western Branch, South Charleston, Clark County: 428 acres